Single-Neutron Levels Near the N=82 Shell Closure

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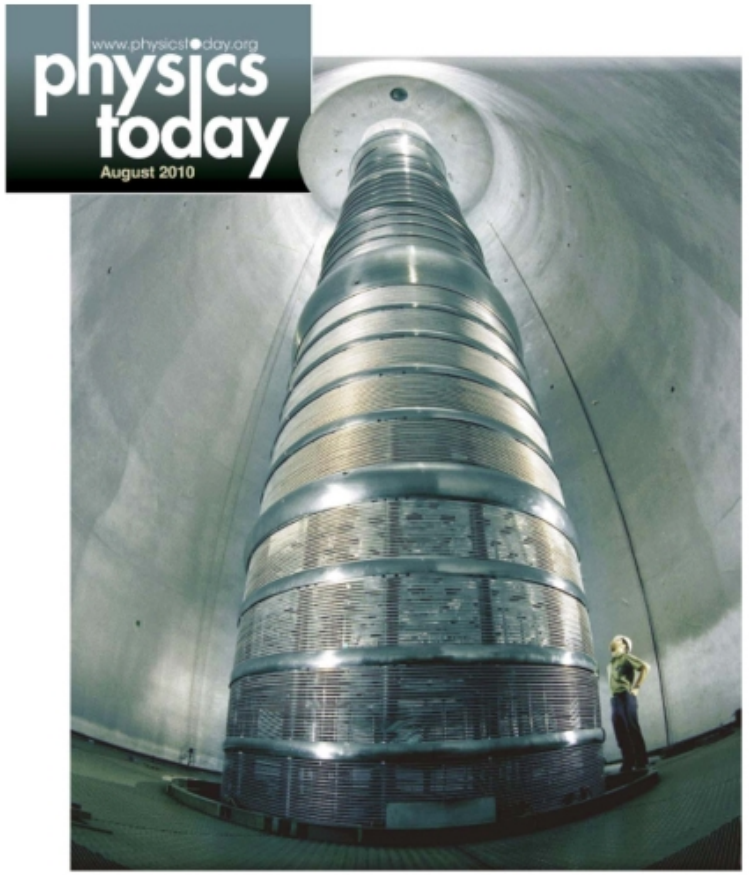
One neutron from ^{132}Sn

Recent experiments at the Holifield Radioactive Ion Beam Facility (HRIBF)

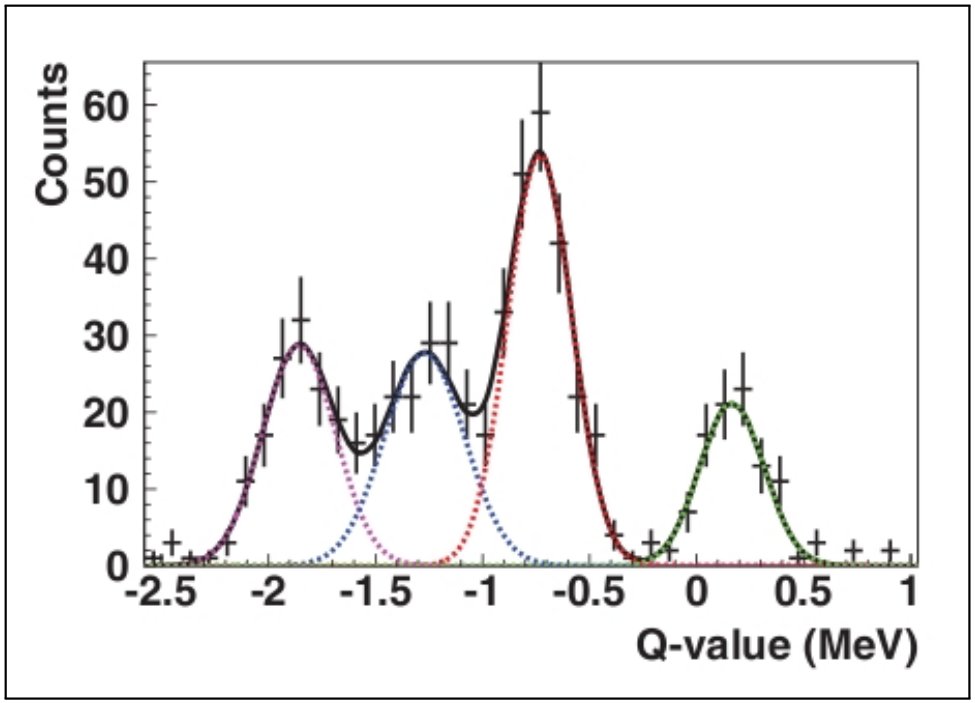
- K.L. Jones et al. studied ^{133}Sn via ^{132}Sn(d,p) was published in Phys. Rev. C and Nature; featured on the cover of Physics Today
- R.L. Kozub et al. studied ^{131}Sn via ^{130}Sn(d,p) and recently submitted the results for publication



Doubly magic shell game

^{132}Sn(d,p)

Q-value Spectrum for ^{132}Sn(d,p) in Inverse Kinematics



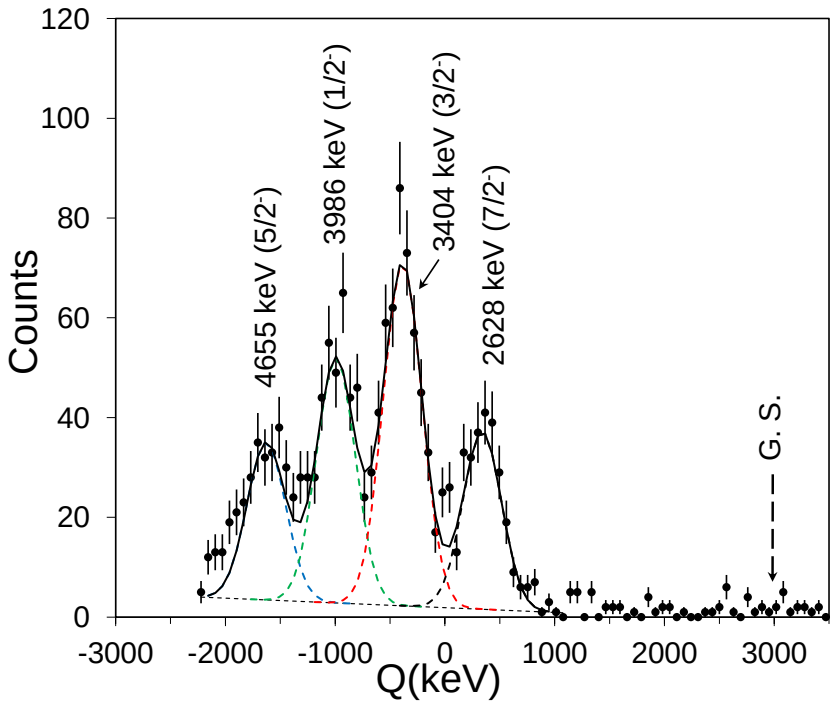
- Validated ^{132}Sn as a doubly-magic nucleus
- Spectroscopic factors near 1.0 indicated the states in ^{133}Sn are pure single-particle

E_x (keV)	J^π	Configuration
0	$7/2^-$	$2f_{7/2}$
854	$3/2^-$	$3p_{3/2}$
1363	$(1/2^-)$	$(3p_{1/2})$
2005	$(5/2^-)$	$(2f_{5/2})$

K.L. Jones et al. Nature **465**, 454 (2010) and Phys. Rev. C **84**, 034601 (2011).

^{130}Sn(d,p)

Q-value Spectrum for ^{130}Sn(d,p) in Inverse Kinematics



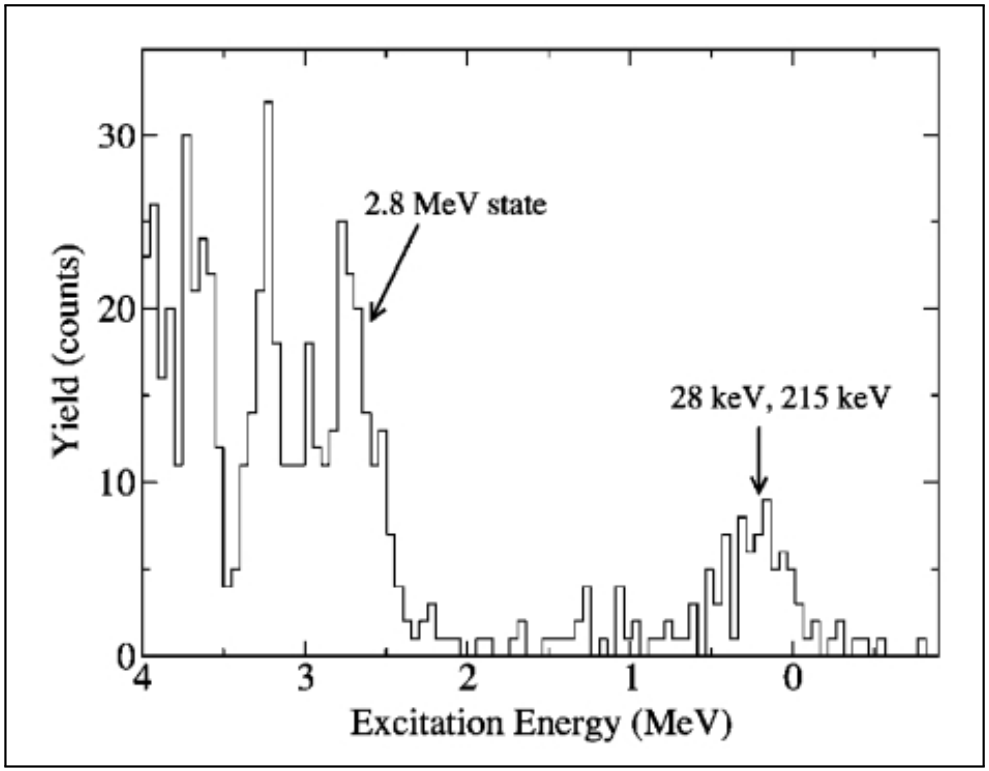
- Q-value spectrum overlapped very nearly with the results from ^{132}Sn(d,p)
- Spectroscopic factors for ^{131}Sn were between 0.7 - 1.0
  - Indicates the states in ^{131}Sn are largely single-particle

E_x (keV)	J^π	Configuration
2628	$7/2^-$	$2f_{7/2}$
3404	$3/2^-$	$3p_{3/2}$
3986	$1/2^-$	$3p_{1/2}$
4655	$5/2^-$	$2f_{5/2}$

R.L. Kozub et al., submitted for pulication.

Back to Stability with ^{124}Sn

Q-value Spectrum for ^{124}Sn(d,p) in Inverse Kinematics



- K.L. Jones et al. studied states in ^{125}Sn through the (d,p) reaction in inverse kinematics using silicon detectors
- I. Tomandl et al. studied states in ^{125}Sn through both the (n,γ) reaction and the (d,p) reaction in normal kinematics with the Q3D magnetic spectrograph
  - Measured greater than 400 states in ^{125}Sn
  - Since ^{124}Sn is stable it allows for normal kinematics, this is not true for higher mass Sn isotopes

K.L. Jones et al., Phys. Rev C **70**, 067602 (2004).

Reminder: What has been studied

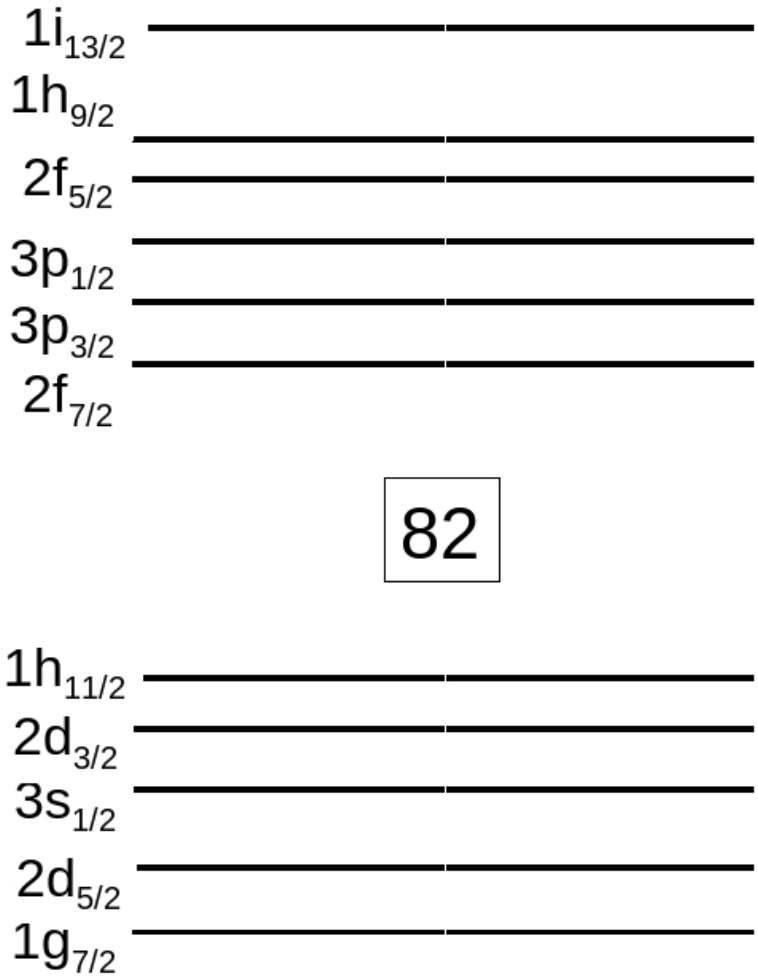
- ^{133}Sn is one neutron above the double shell closure at Z=50 and N=82
  - ^{133}Sn has been verified to contain nearly pure single-particle states through ^{132}Sn(d,p) in inverse kinematics
- ^{131}Sn is one neutron below the double shell closure at Z=50 and N=82
  - ^{130}Sn(d,p) in inverse kinematics has been shown to populate highly single-particle states
- ^{124}Sn is stable and therefore normal kinematics experiments are possible
  - States in ^{125}Sn have been studied through ^{124}Sn(d,p) in both inverse and normal kinematics as well as ^{124}Sn(n,γ)

Comparison of the proposed $f_{7/2}$ state

Reaction	E_x (keV)	J^π	Spectroscopic Factor
^{132}Sn(d,p) [1]	0	$7/2^-$	1.00±0.08
^{124}Sn(d,p) [2]	2754.8	$7/2^-$	0.30

[1] K.L. Jones et al., Phys. Rev. C **84**, 034601 (2011).
[2] I. Tomandl et al., Phys. Rev. C **83**, 044326 (2011).

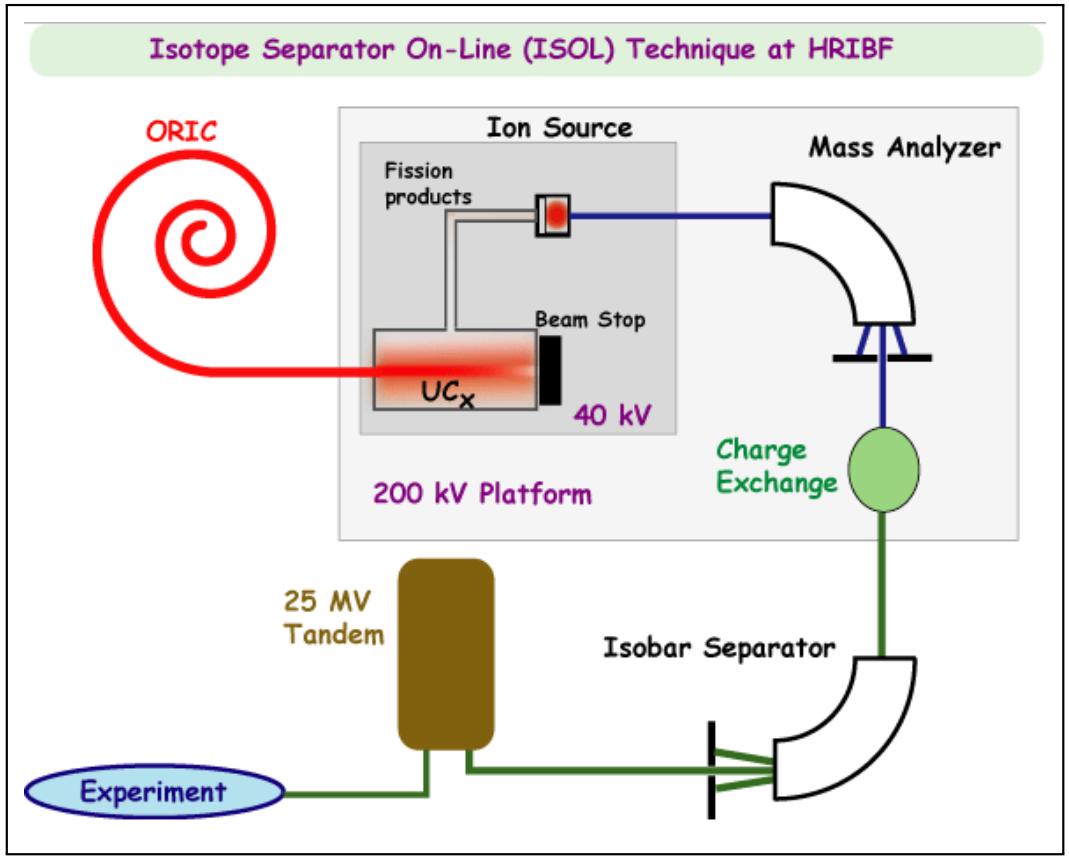
The Big Question: How do these States Evolve Between the Double Shell Closure and Stability?



- Energy levels and fragmentation for single-particle states in ^{127,129}Sn will help constrain theoretical structure model parameters
- Better model parameters will increase the predictive power of such models for neighboring nuclei

Radioactive Ion Beams at HRIBF

- Proton beam impinged upon uranium carbide (UC_x) target
- Sulfur gas in the Ion Source bonded with tin-ions exiting the UC_x target to aid in beam purification
- Mass Analyzer selected for tin-sulfide (SnS) molecules with $A=A_S+A_{Sn}$



- SnS molecules broken up in Charge Exchange Cell producing negative-ions accelerated to 630 MeV in the 25-MV Tandem

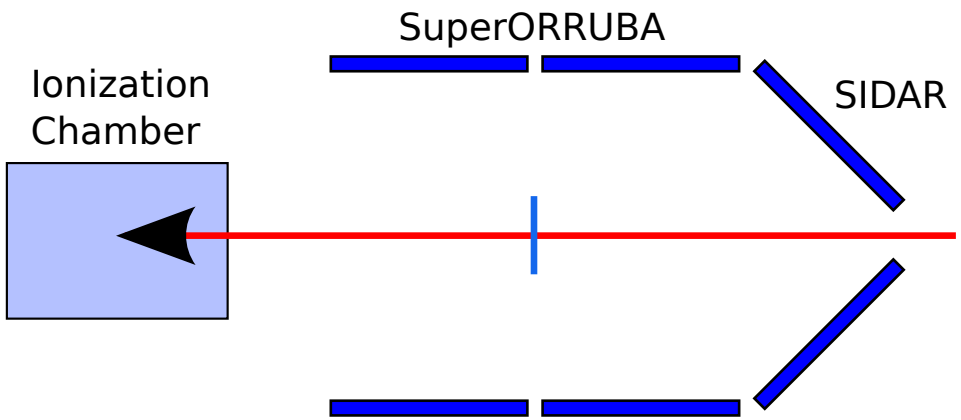
http://www.phy.ornl.gov/hribf/accelerators/

(d,p) Reaction in Inverse Kinematics

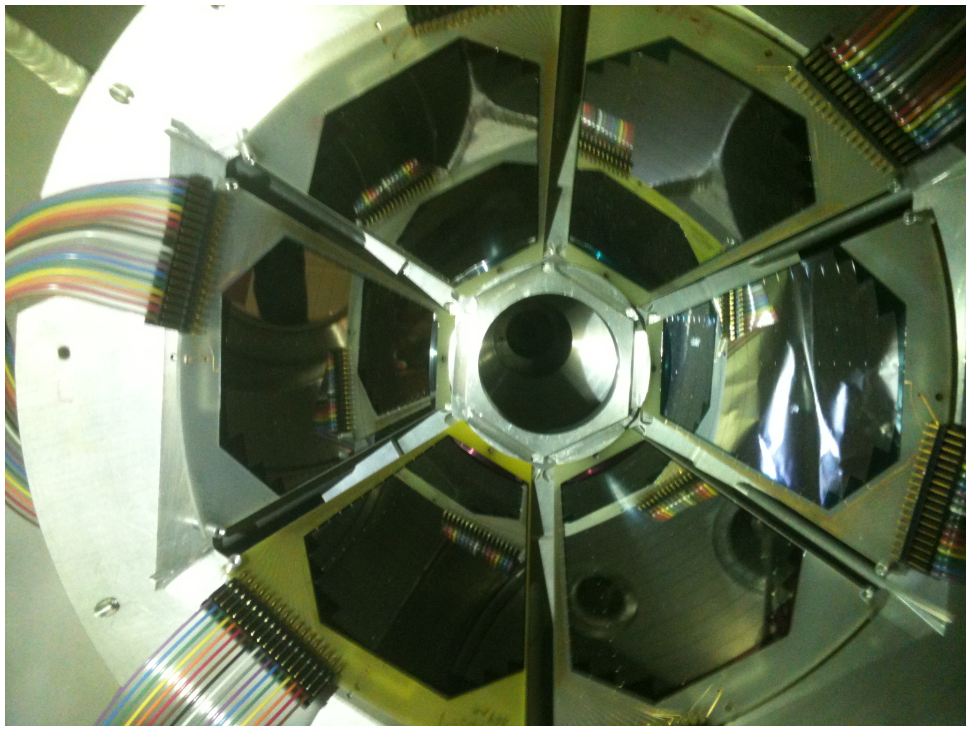
- RIB impinged upon 242 μg/cm^2 CD_2 target
  - $E_{Beam} \approx 5$ MeV/u
  - 100,000 pps for ^{126}Sn ($\approx$1 day)
  - 35,000 pps for ^{128}Sn ($\approx$4 days)
- In the lab frame:
  - Protons, deuterons, and carbon in the target are elastically scattered forward of 90°
  - Lowest energy reaction protons will be ejected backward of 90°

Detectors

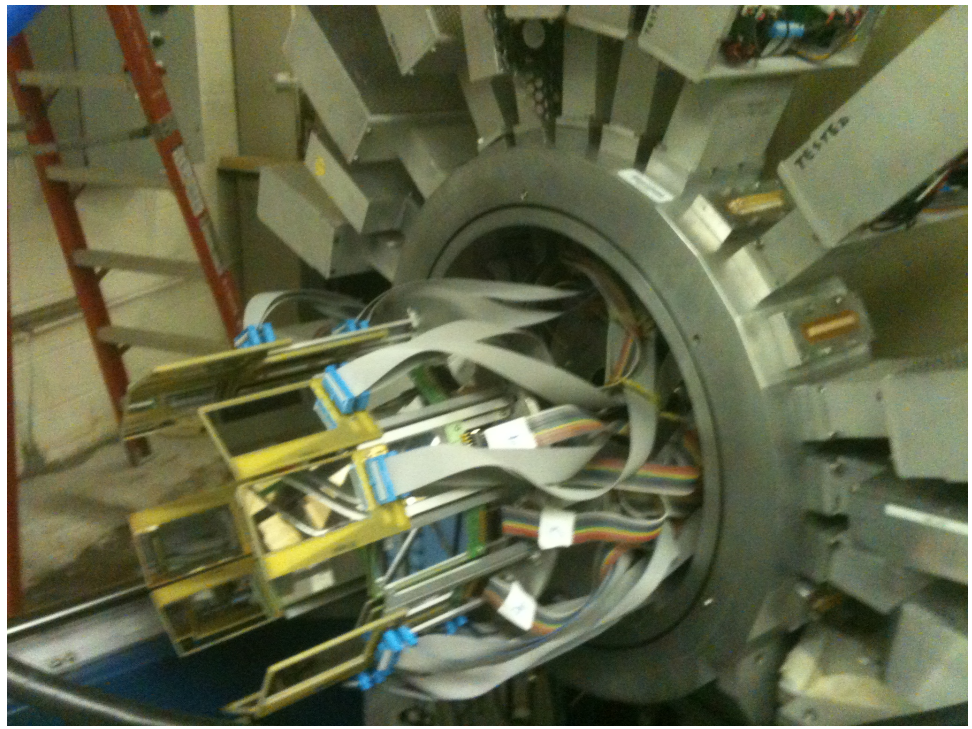
- An ionization chamber was placed at 0°
- 2 silicon strip detectors (SuperORRUBA) covered lab angles from 55°-90°
- 6 silicon strip detectors (SuperORRUBA) covered lab angles from 90°-125°
- 6 annular silicon strip detectors (SIDAR) covered lab angles from 125°-160°
- See S. Ahn's poster for more details on SuperORRUBA



SIDAR detectors in "lampshade" configuration

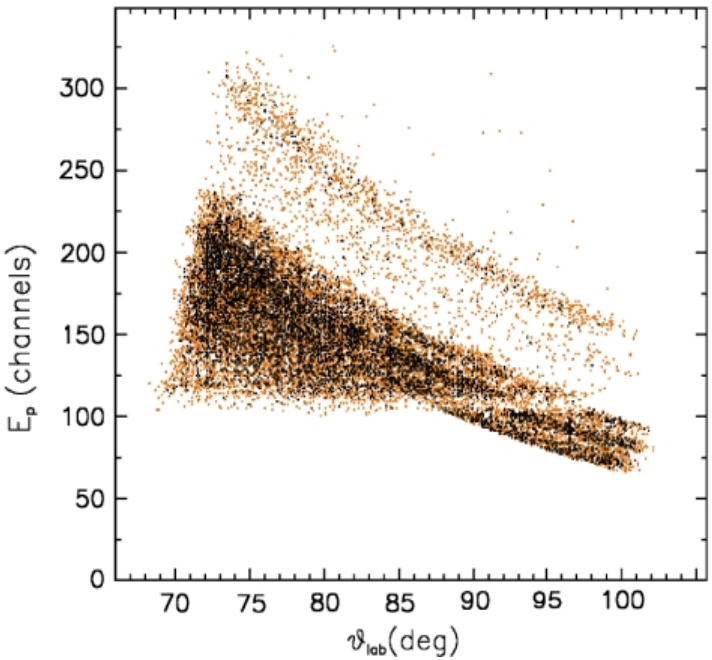


Ring of SuperORRUBA detectors

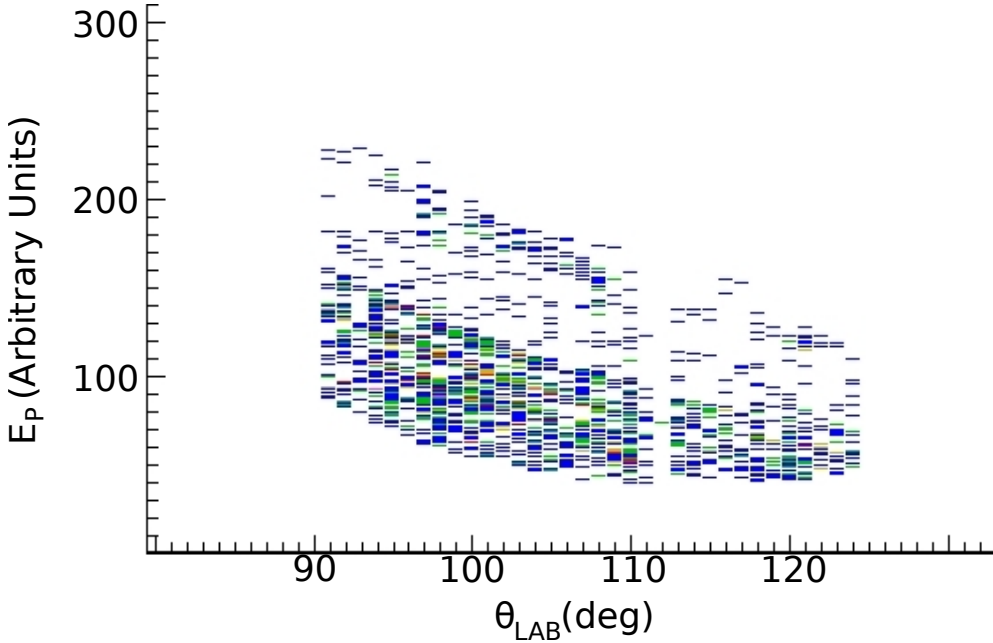


Preliminary results look very similar to previous work in this area!

^{124}Sn(d,p) in Inverse Kinematics



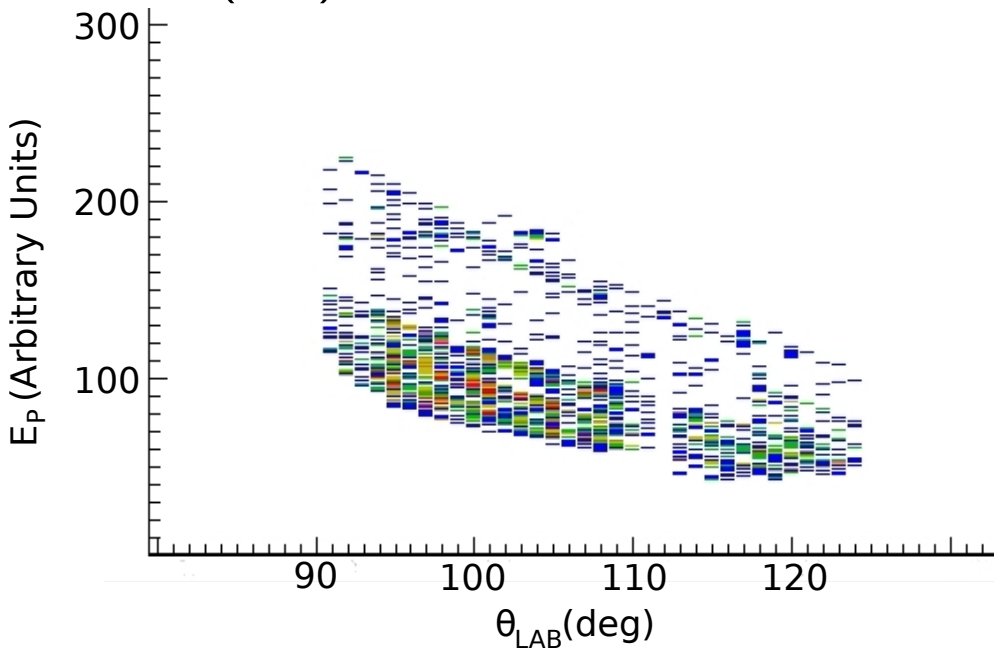
^{126}Sn(d,p) in Inverse Kinematics



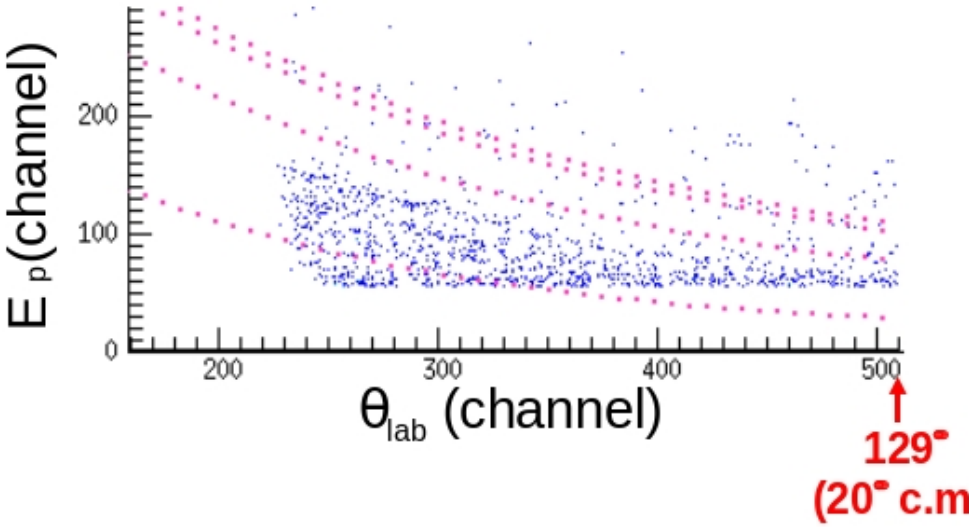
K.L. Jones et al., Phys. Rev C **70**, 067602 (2004).

Preliminary results look very similar to previous work in this area!

^{128}Sn(d,p) in Inverse Kinematics

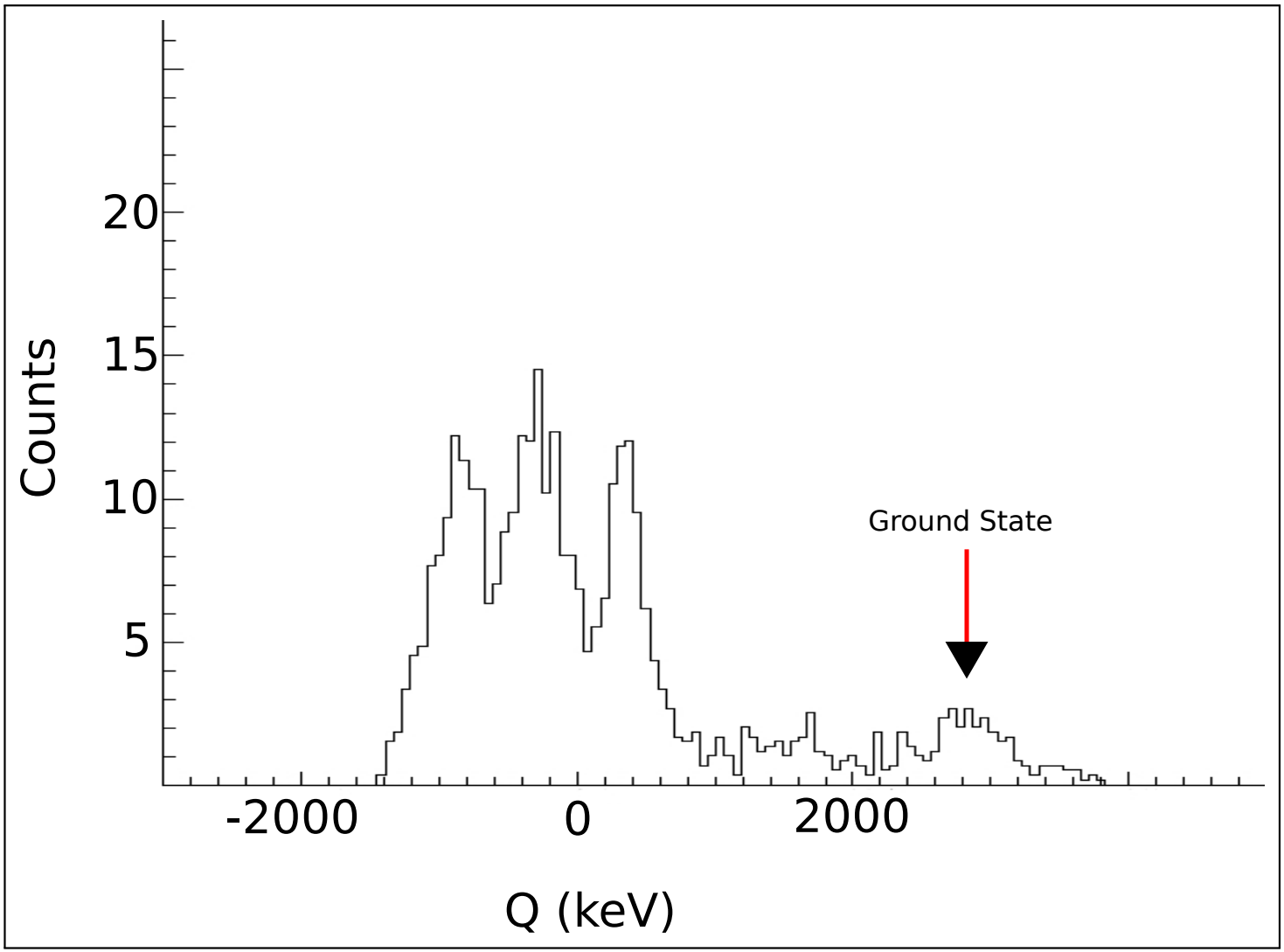


^{130}Sn(d,p) in Inverse Kinematics



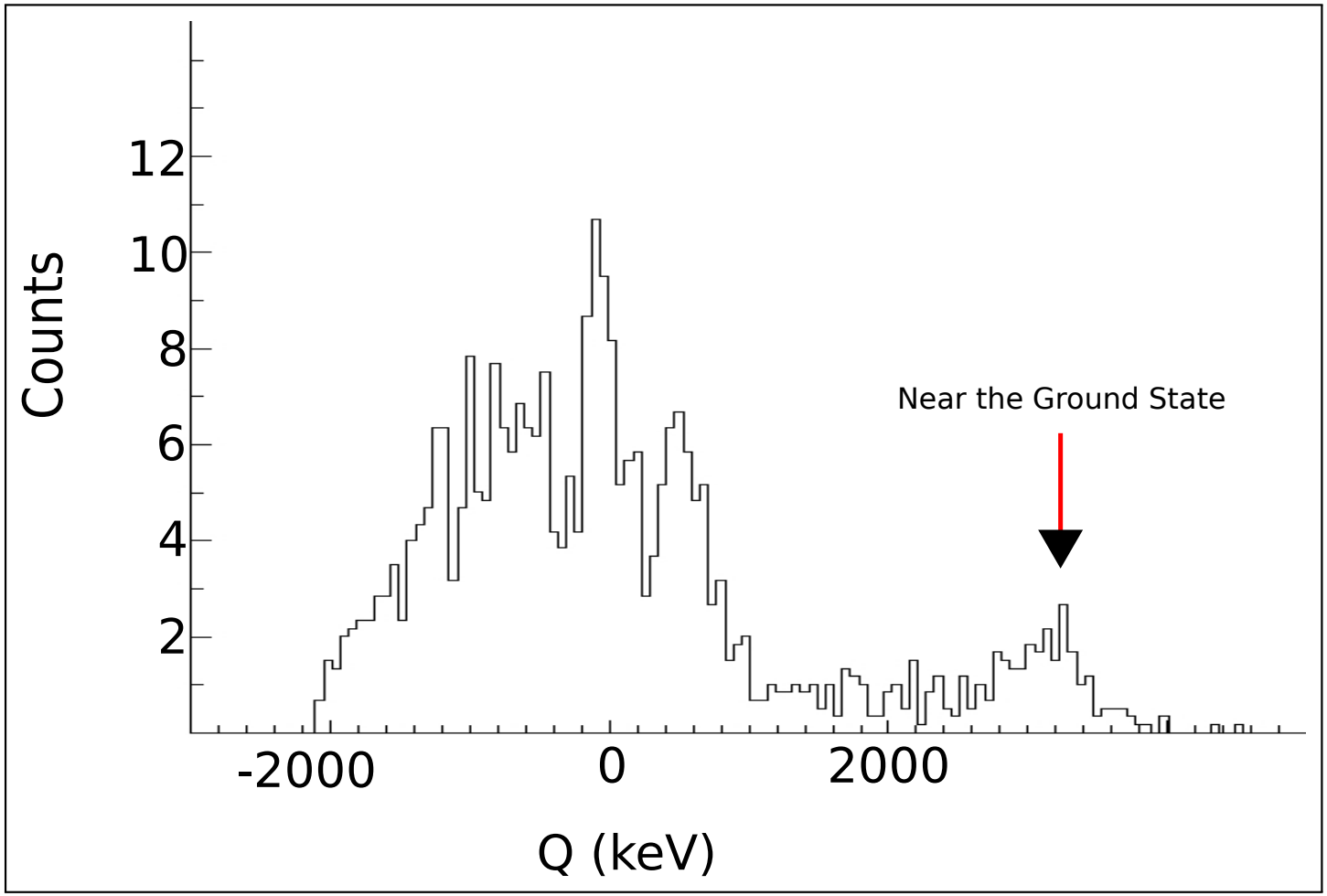
R.L. Kozub et al., submitted for pulication.

Q-value Spectrum for ^{128}Sn(d,p) in Inverse Kinematics



- States below the N=82 shell closure are weakly populated
- 3 states above the the N=82 shell closure
- Similar to Q-value spectrum for neighboring nuclei

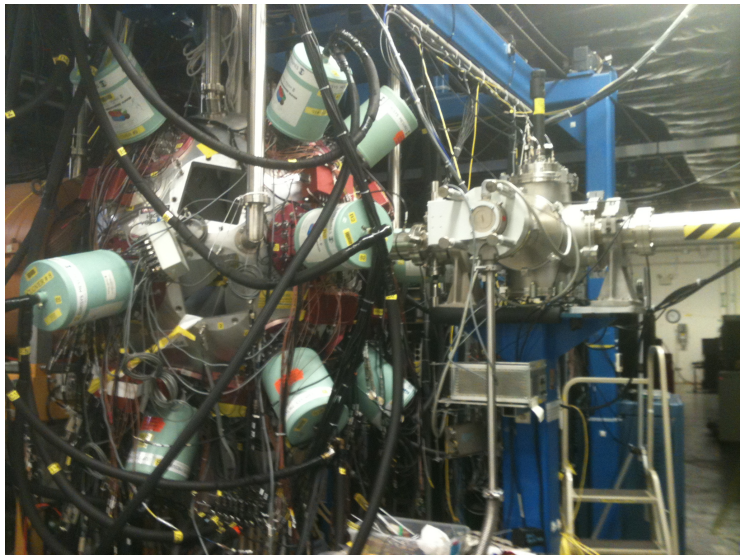
Q-value Spectrum for ^{126}Sn(d,p) in Inverse Kinematics

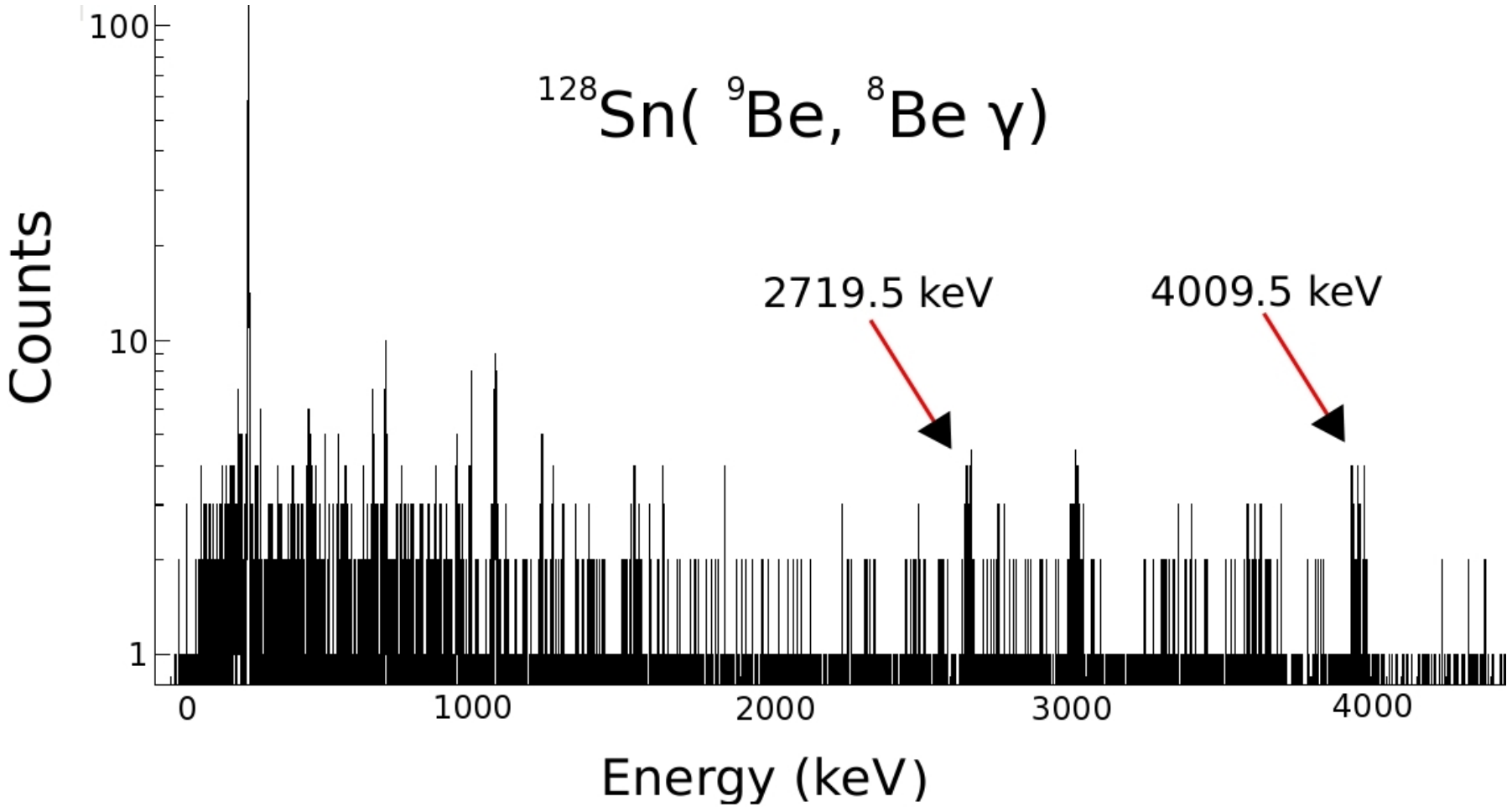


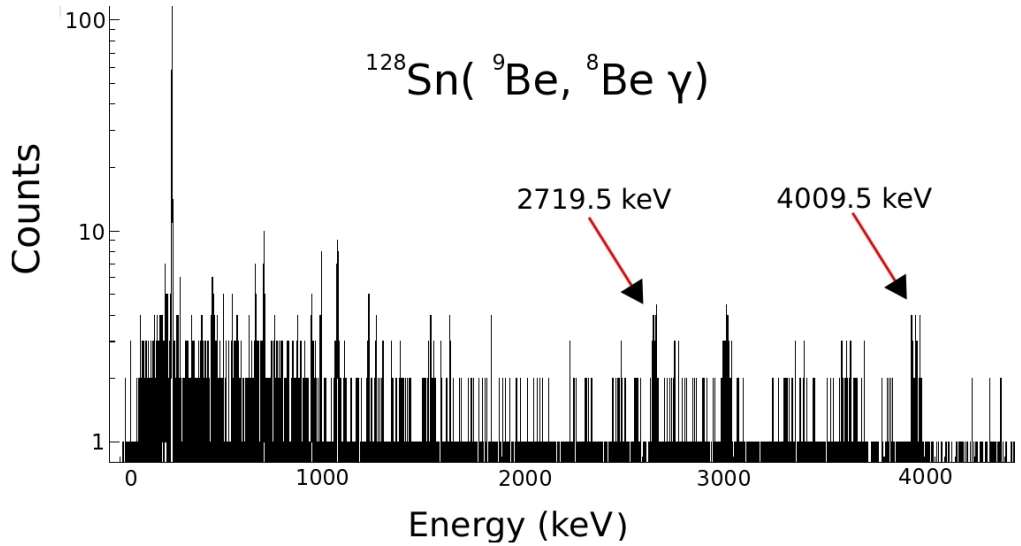
- States below the N=82 shell closure are weakly populated
- 3 or more states above the the N=82 shell closure
- Short run time leads to low statistics

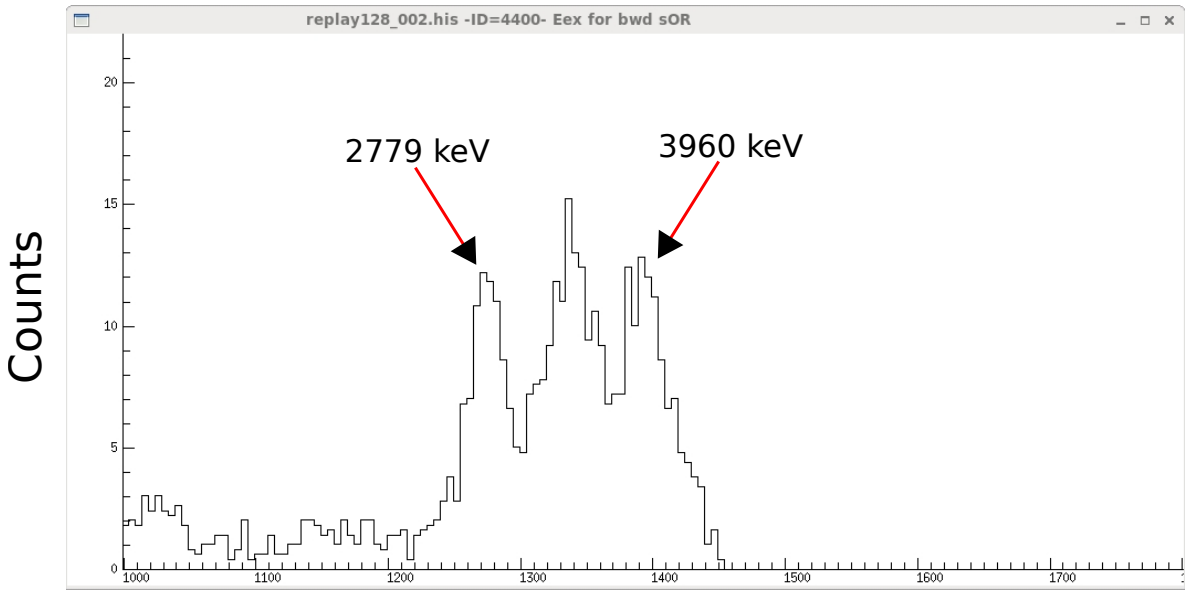
Particle-Gamma Coincidences

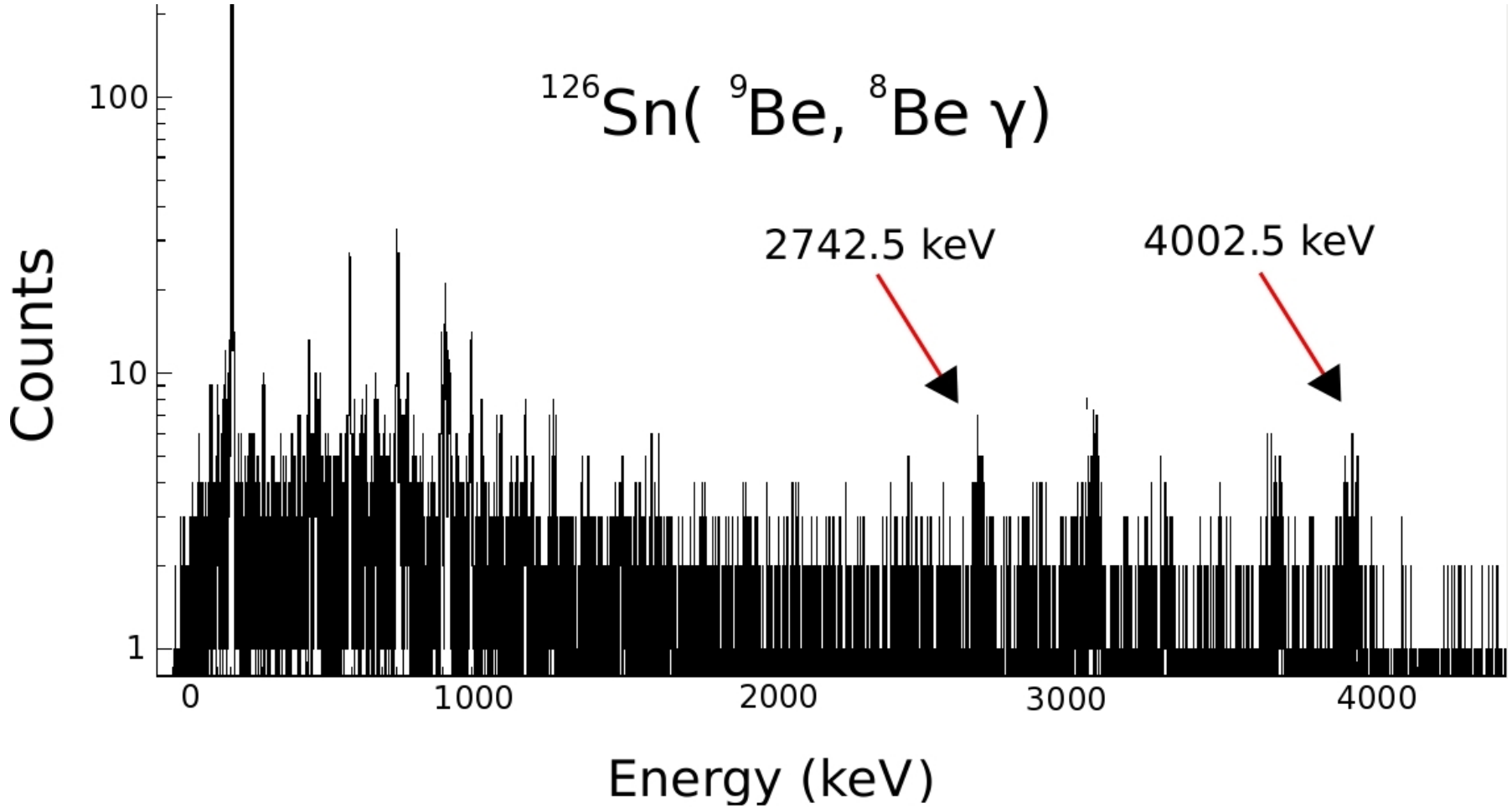
- D.C. Radford and coupled A. Galindo-Uribarri CLARION (Ge-clovers) and HyBall (CsI)
  - Useful for many techniques including (^{9}Be, ^{8}Be γ)
- See J.M. Allmond's talk from 4:45pm-5:05pm later today for more detector details

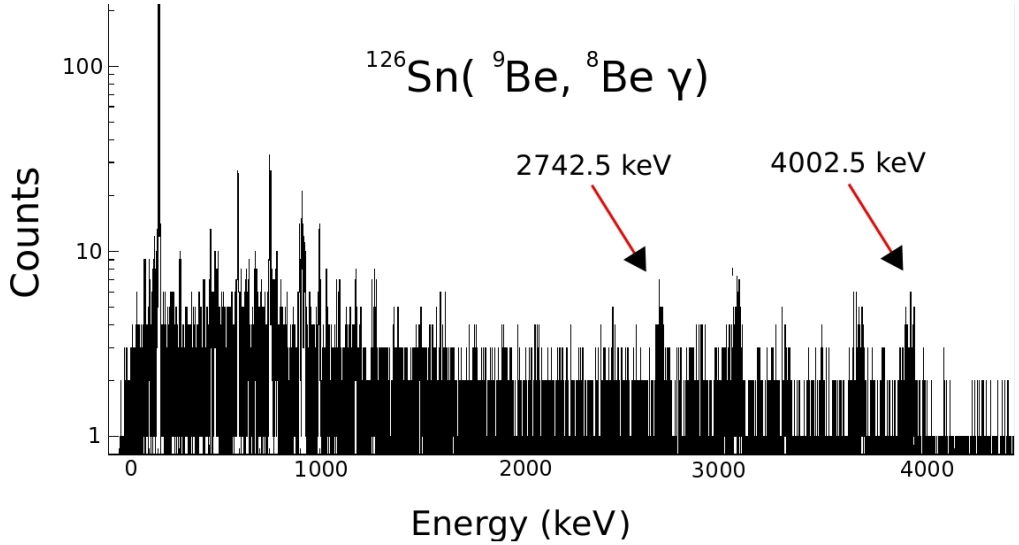


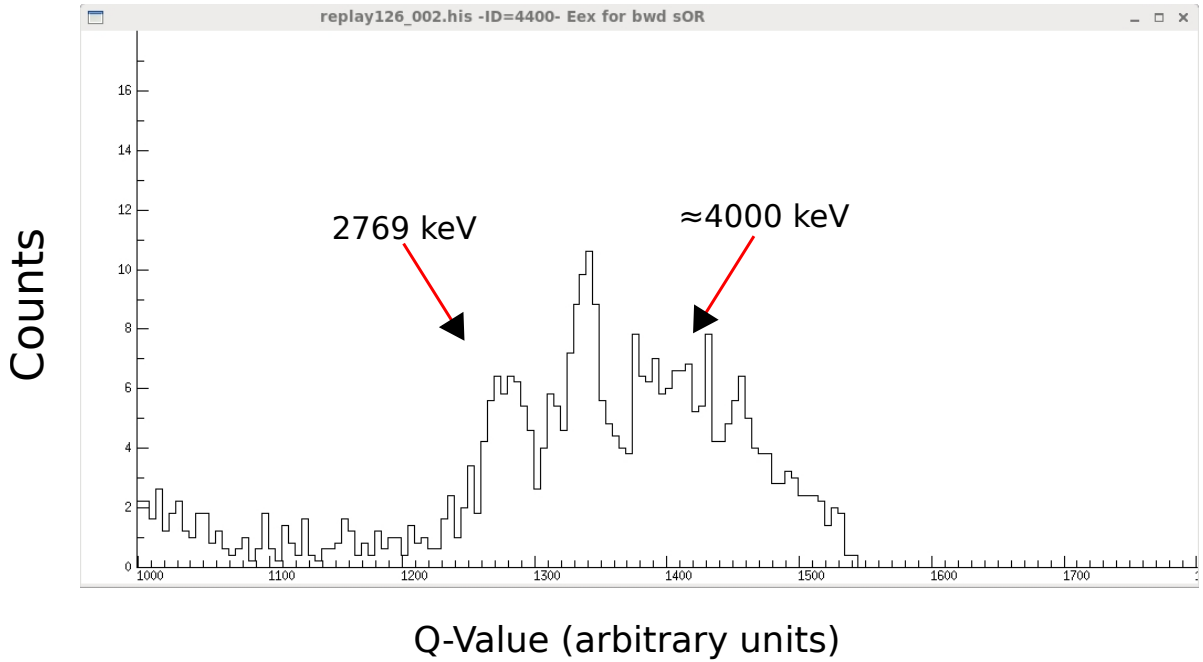

^{128}Sn(^{9}Be, ^{8}Be γ)
2719.5 keV
4009.5 keV
Counts
100
10
1
0
1000
2000
3000
4000
Energy (keV)


^{128}Sn(^{9}Be, ^{8}Be γ)
2719.5 keV
4009.5 keV
Counts
Energy (keV)


replay128_002.his -ID=4400- Eex for bwd sOR
2779 keV
3960 keV
Counts
Q-Value (arbitrary units)

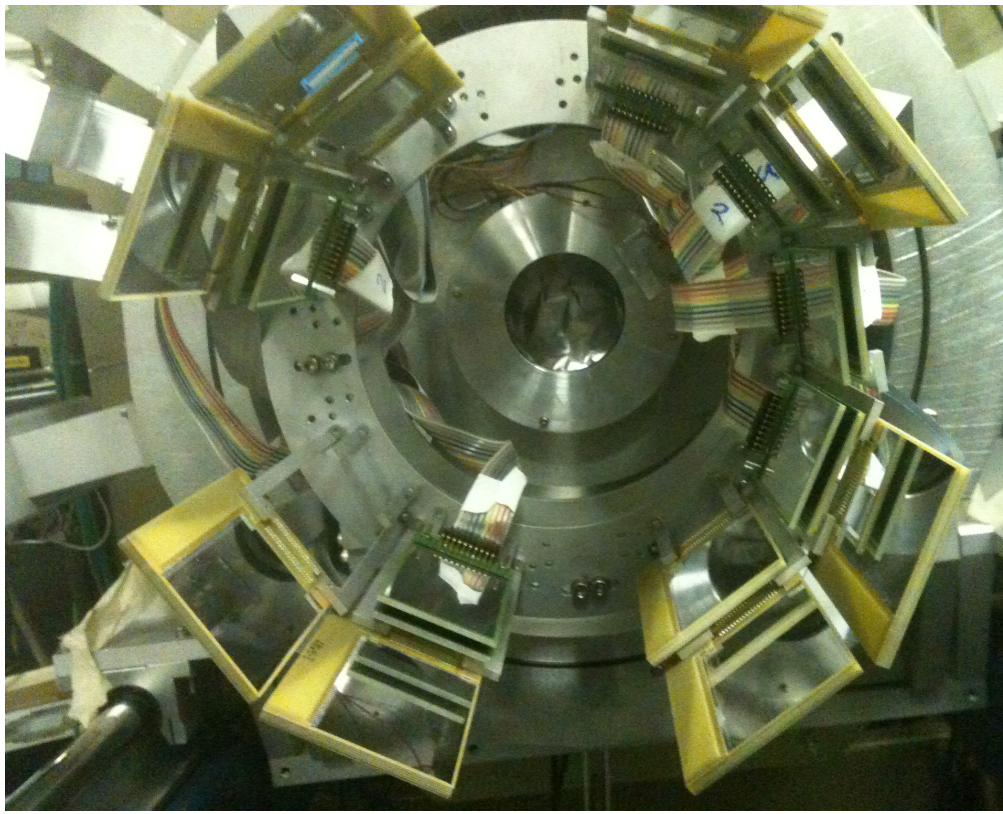

^{126}Sn(^{9}Be, ^{8}Be γ)
2742.5 keV
4002.5 keV
Counts
100
10
1
0
1000
2000
3000
4000
Energy (keV)


^{126}Sn(^{9}Be, ^{8}Be γ)
2742.5 keV
4002.5 keV
Counts
100
10
1
0
1000
2000
3000
4000
Energy (keV)


replay126_002.his -ID=4400- Eex for bwd sOR
2769 keV
≈4000 keV
Counts
16
14
12
10
8
6
4
2
0
1000
1100
1200
1300
1400
1500
1600
1700
Q-Value (arbitrary units)

Outlook

- Preliminary anlysis indicates we observe the same f and p-states studied in previous experiments
- Gamma-ray data from (^{9}Be,^{8}Be γ) reaction will provide high resolution energy centroids
- Plans to verify transfered angular momentum and extract spectroscopic factors
- Discussions with structure theorist Shi-Sheng Zhang



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